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# THE EFFECT OF N550 CARBON BLACK IN POLYESTER RESIN FOR FIRE-RETARDANT APPLICATION IN MARINE COMPOSITE

Asmawi A. M.[1], Syarmela Allauldin[1], Nurshahnawal Yaacob[1], Asmalina Saat[1], Azura Ahmad Radzi[1], Mohd Zamani Ahmad[2] and Ahmad Faizal Ahmad Fuad[3]
[1]Universiti Kuala Lumpur MIMET, Lumut, Perak, Malaysia
[2]Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia
[3]School of Ocean Engineering, Universiti Malaysia Terengganu, Kuala Nerus, Terengganu, Malaysia
E-Mail: awie1001@hotmail.com

**ABSTRACT**

This paper presents the experimental investigation on the influence of N550 carbon black (CBN550) series in polyester resin (wax and non –wax type). The CBN550 was added into polyester resin at different weight percentages with a curing agent. The investigation is mainlyto study the effect on fire retardance application in marine composite structure. The fire-resistant structural composites samples of 1000 mm by 1000 mm prepared which consist of 10 of composite mats layer in combination of CSM 450 g/m² and Woven Roving 600 g/m². The carbon black (CB) volume fraction range from/with 0% to 20% volume fractions. Optical observation revealed the most suitable fraction of CBN550 in wax polyester resin is at 10% and non-wax polyester resin is also at 10%. The fire resistance behavior of this CBN550 - CSM 450 g/m² - Woven Roving 600 g/m² composite (polyester wax) and polyester non wax was investigated by Fire Test Procedure Code-Resolution A.653 [1]. Though smaller filler size escalates the rheological behavior and values outstandingly at initial reading compare to large particles but it slow down the curing processdue to its small particle size, large surface area and high dispersion rate. Experimental data showed the retardance level has been increased up to 56.66% in non-wax type polyester resin (10%/CBN550) and 30.14% in wax polyester resin (10%/CBN550). The improvement in fire resistance points are due to the presence of CBN550 which acts as a positive additive in both polyester resin wax and non-wax. Filling CBN550 in polyester resin also reduces the cost of theend products.The preliminary results suggested that CBN550should attend to next level of experiment investigation such as oxygen content, TG value, microstructure as well as mechanical destructive test. The CBN550 could be a suitable candidate for fire retardance application in marine composite structure.In conclusion, crystallinity of polyester resin increases with additional of CB particles

**Keywords:** Polyester, carbon black, volume fraction, fire retardance.

## INTRODUCTION

Today's materials advancement demands for better materials performance at acceptable of entry investment margin. Boating is one of the materials application which appeals of cheap, strong, durable, ease of maintenance, fuel efficiency and light structure. This scenario has paved the way for the generation as fossil fuel keeps on fluctuating from time to time.

Traditionally, common boating materials are wood, steel, aluminium and plastic. Each building material offers its own characteristics, advantages and also disadvantages. In the last 20 years back, plastic and aluminium based made a larger market percentage in boats. Technically, the fiber glass reinforced plastic composite (FRPC) construction offers many advantages over steel or aluminum construction. Benefits include better surface aesthetics, lack of corrosion, lower superstructure weight leading to greater payload or speed potential and good environmental properties. In several research and innovation stated that an important safety concern is that most FRPC materials have poor fire resistant properties[2-4], such as short ignition time and high rates of heat release, smoke production and flame spread, while it is generally recognized that composites have much lower thermal conductivity than metallic material. The FRPC is combustible based material and some of the common boat polyesters have a heat deformation temperature as low as 70 degrees Celsius. These factors make it difficult for composites to meet the stringent fire safety requirements applied to offshore oil and gas platforms.

Malaysian Marine Departments (Ministry of Transportation) starts demanding stricter requirements concerning fire retardant and heat resistant materials especially for new Malaysian FRPC boat/vessel. This requirement is supported by Ship Classification of Malaysia (SCM) initiative to strengthen their guidelines on materials applied for this purpose. In any fire accident, these composite materials are known to generate a complex mixture of combustion products comprising of highly toxic gases, organic vapours and particulate matter including fine fibre [5-7]. There are a number of researcher have proposed modified composites with additives[7-11] for improved fire performance might have low flammability index and heat release rates, but these advantages are sometimes subverted by very high toxicity hazard from the combustion products. They are all agreed on the flame retardants are incorporated in FRP composites to achieve a desired fire resistance. Flame retardants suppress combustion by acting either through the vapour phase or the condensed phase by chemical and/or physical mechanisms. On any compound containing higher structured blacks will have highest modulus[12]. Nevertheless, in Organo phosphorous and nano-clay additives to resins that the addition of even 7.5% and 3% phosphate can result in as much as 37% increase in time to material ignition[13]. Modifying the burning behavior of a resin may result in other properties being adversely affected[14], and it is important to bear this in mind when choosing a resin system to meet specific fire performance criteria, for instance, laminates made using low fire hazard resins generally have poorer weather resistance than normal laminates, so they need the protection of a quality gel coat if they are to be used externally.

Nabaltec AG [15]from German has produced a non-combustible material for plastic retardant application. A very stable substance, which starts to degrade at 200 degree Celsius in temperature and ecological to environment. However, the initial cost for Apyral - Aluminium Trihydrate (ATH) as additive is considered high to Malaysian local market. An alternative or an option for retardant application is now to test carbon black [16, 17]feasibility in ester group application. The carbon black is petroleum basis and it is supported by initial on shelf cost which is 50% cheaper in the market.

## OBJECTIVE OF THE STUDY

The investigation is mainly to study the CBN550 effect on polyester resin for fire retardance application in marine composite structure. This work is an attempt at retardant fabrication and to get into the mainstream of the technological frontiers of the 21st century at acceptable reduction of flammability and cost.

## EXPERIMENTAL PROCEDURES

The main materials under investigation are listed in Table-1. All of it came from various origins and it is divided into three sections. In making the FRPC panel, two types of general purpose resin are used. They are Wax Type Resin (WTR) and Non-Wax Type Resin (NWTR). The CBN550 characteristic's is shown in Table-2. Table-3 summarized the suitable solution composition of CBN550 in FRPC. The amount of N550CB plays important role in determining the suitable solidification and consolidation.

Through visual inspection technique, the sample of CB0, CB1, CB2, CB3 and CB4 solutions have shown its characteristics. Those with defects and cracks will be rejected for further investigation. CB4 consolidated well with NWTR and CB3 solution matched with WTR (refer Table-3). The unknown suitable or match percentage value of N550CB need to be explored, then the flame distance is measured over a certain period of time. The FRPC panels were fabricated using hand lay-up process. Before laying-up, the mold is prepared with a release agent to ensure that the part will not adhere to the mold. Reinforcement fibers are cut and laid in the mold. Resin must then be catalyzed and added to the fibers. Brush, roller or squeegee is used to impregnate the fibers with the resin. The amount of resin and the quality of saturation must be controlled during the process. Otherwise, there will be a risk of overheating, which could result in warping and weakening of finished product

**Table-1.** Summary of theIapologise for the delay in replying. materials – type/supplier/size.

| *Materials* | *Supplier* | *Size* |
|---|---|---|
| Unsaturated wax polyester | Norsodyne | 3330W |
| Unsaturated non wax polyester | Norsodyne | 3330 |
| Aluminum hydroxide (Apyral) | Nabaltec product | - |
| N550 Carbon Black | Thai Carbon Black Public Co., Ltd. | Refer table 2.2 |
| Glass Fiber Woven Roving (WR) | Changzhou Protech Industry Co., Ltd. | 300gm/m$^2$ |
| Chopped Strand Glass (CSM) | Changzhou Protech Industry Co., Ltd. | 450gm/m$^2$ |

**Table-2.** Classification and characterization of commercial carbon black.

| *ASTM Designation* | *Type Code* | *Type* | *Typical N2SA m$^2$/g* | *Typical avg. Particle, nm* |
|---|---|---|---|---|
| N550 | FEF | Fast extrusion furnace | 41 | 40-48 |

**Table-3.**Summarized the suitable solution composition of CBN550in FRPC.

| *Component (s)* | *Solution composition (wt %)* | | | | |
|---|---|---|---|---|---|
| | CB0 | CB1 | CB2 | CB3 | CB4 |
| Resin (Wax/Non wax) | 100 | 100 | 100 | 100 | 100 |
| Carbon black | 0 | 5 | 10 | 15 | 20 |
| MEKP | 2 | 2 | 2 | 2 | 2 |

Even more importantly, there is a risk of damage to the mold surface due to excessive heat build-up[18]. Flammability tests for 0%, 10% of N550CB/WTR, 10% of N550/NWTR and Aluminum hydroxide (Apyral) are prepared according IMO FTP Code – Resolution A.653. Controlled environment flammability test is performed on the sample. Each of 1000 mm x 1000 mm sample was placed on a testing stand and flame from gas burner was applied for surface flammability test.

## RESULTS

The distance of the flame spreading on the sample panels for both testing times were then measured and repeated for all three replicates. Smoke produced by samples panel are visible. For the modified samples, the ignition times ranged from 3 to 5 minutes compared to each other and the summary as in Table-3.1 and plotted in Figure-1 to Figure-8.

Figure-1 and Figure-2 shows reduction in the fire distance for both 10% N550/WTR and 10% CBN550 NWTR when samples are exposed to fire for 5 minutes as compared to the 0% CB mixture. The retardant is quite significant shows in NWTR in 5 minutes reaction which

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stands at 45.71% flames reduction. A more extreme reduction can be seen after 10 minutes the samples exposed to fire as seen in Figure-3 and Figure-4. Whereby the 10% CBN550 NWTR sample performance almost matched the performance with 5% and 10% Apyral. As for Figure 5 and Figure-6, the diameter of the flame spread on the sample reduced in the 10% CBN550 for both WTR and NWTR but covered a large area compared to samples with Apyral. However, it is a good sign, since the addition of the carbon black can visually reduce the flame area as well as shown in Figure-7 and Figure-8.The flame travelled distance is reduced proportionated with CBN550 content. And to be amazed the flame travelled distance is slightly better on 10% CBN550 as checked with Apyral at 5%.

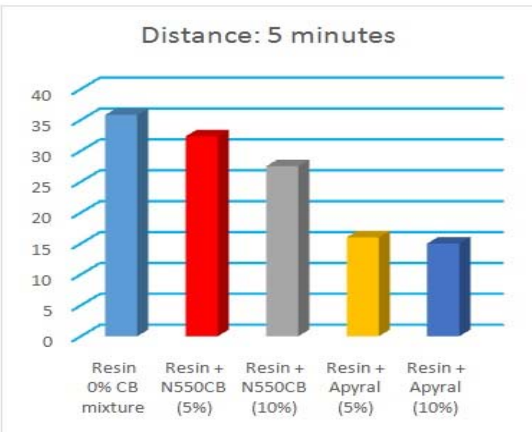


**Figure-1.** Bar chart of CBN550 in WTR (5 minutes range).


**Figure-2.** Bar chart of CBN550 in NWTR (5 minutes range).

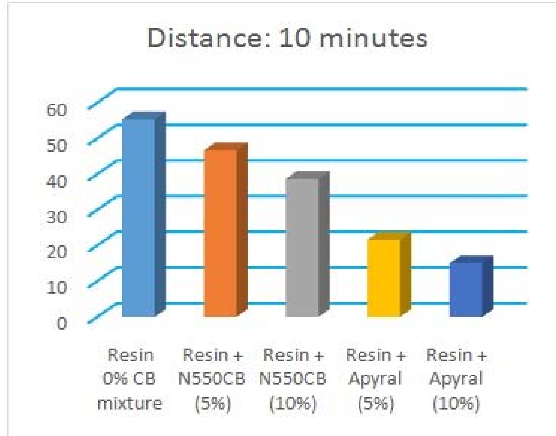


**Figure-3.** Bar chart of N550CB in WTR – 10 minutes range.

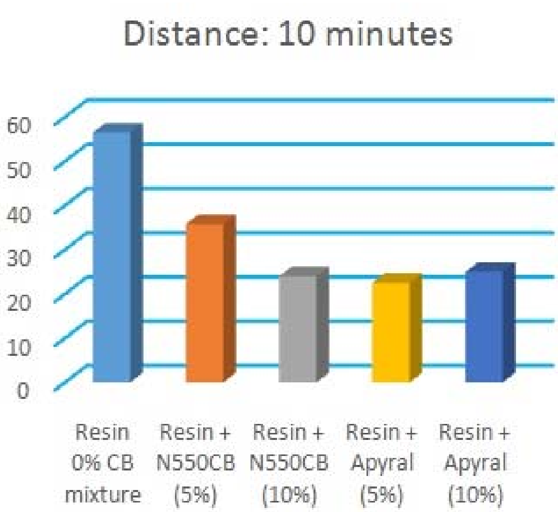


**Figure-4.** Bar chart of CBN550 in NWTR (10 minutes range)

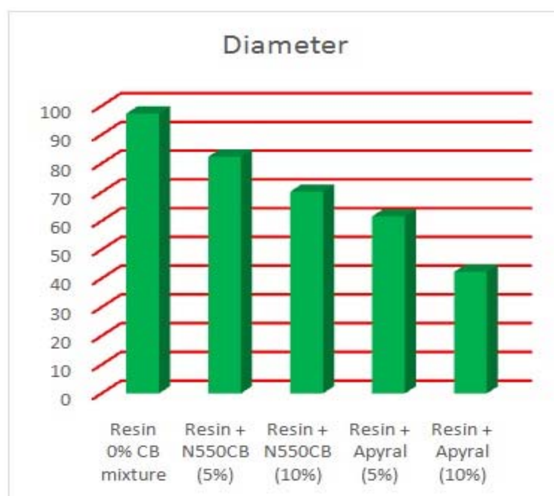


**Figure-5.** Diameter chart of CBN550 in WTR.

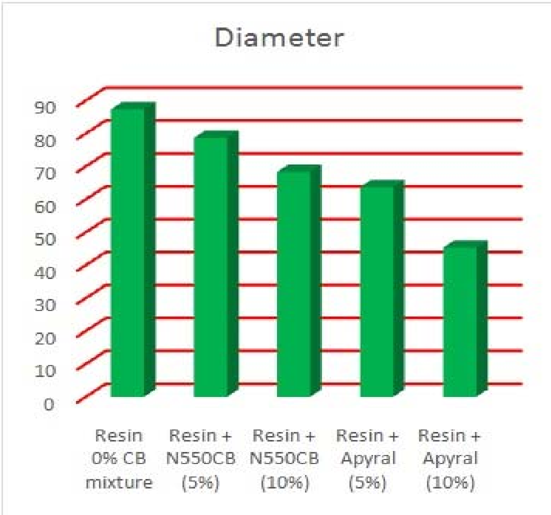


**Figure-6.** Diameter chart of CBN550 in NWTR.


**Figure-7.** Flame distance chart of CBN550 in WTR.


**Figure-8.** Flame distance chart of CBN550 in NWTR.

## CONCLUSIONS

The modification made to the FRPC, significantly improved the flame retardant properties in both polyester resin. The preliminary results of CBN550 mixture in WTR and NWTR, shown as a good constituent as an alternative material in common resin application. With an investment of RM 1.00/100grams of CBN550 per kilogram of NWTR, it helps of 56.66% increase in retardant level. Same goes to WTR; with RM 1.00/100grams of CBN550 per kilogram of WTR, 30.14% was recorded in retardant performance. The apyral constituents showed a better performance at higher cost which approximately 50-75% higher than CBN series. It is now realized the CBN550 offers very promising performance for the intended purposes. Therefore, further analysis should be conducted to ensure the durability and practicality of the CBN550 consolidation.

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